Ocean Optical Modeling: The Complex Optical Field Structure and Dynamics of Coastal Case 2 Waters

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LONG-TERM GOAL

Mechanistically-based models and algorithms for ocean optical phenomena are the overall goals for this project. This will ensure the generation of models that are robust and reliable. A standard optical model for the oceans should result. The primary area of interest, at present, is the optics of the coastal ocean system.

SCIENTIFIC OBJECTIVES

My efforts are directed to the construction of a valid, predictive Coastal Ocean Optical Model of Type 2 waters. The primary need is to account for the effects of suspended and resuspended particulate minerogenic matter.

APPROACH

I simulate the solution of the radiative transfer equation by Monte Carlo methods on the Cray T3E. Inherent optical properties from the literature of physics and oceanography are the input parameters. Parallelization of the Monte Carlo simulations has increased their efficiency by orders of magnitude. I utilize a standardized suite of known inherent optical properties called the NRL Optical Model (Weidemann, et al, 1995). This method easily accounts for the complicated non-linearities introduced by multiple scattering, internal radiant emission, and internal apparent radiance sources, i.e. reflective bottoms and wave-disturbed water/air interfaces. New volume scattering functions published by Stramski and Mobley (1997) will also be investigated for their suitability in coastal ocean simulations. Open ocean paradigms have so far provided a successful basis for predictive models of the complex coastal ocean systems. The critical information needed for coastal optical prediction and modeling is the mass and size distribution of minerogenic particulates. This information is provided by Timothy R. Keen with a coastal ocean currents modeling initiative of the Naval Research Laboratory (NRL). Dr. Keen is able to predict mass and size distributions of resuspended minerogenics given information about

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external forcing functions such as tides, wind stress, and waves. Size distributions of resuspended minerogenics allow accurate polydisperse Mie calculations to determine their contribution to the optical properties of coastal ocean systems.
The optical energy trapping hypothesis and 3-parameter model (Stavn et al, 1984) will provide the minimally acceptable description of the coastal ocean light field.

WORK COMPLETED

This project was started only very recently; however, I have successfully completed a "proof of concept" in collaboration with Timothy R. Keen of the Ocean Sensing and Prediction Branch of the Naval Research Laboratory, Stennis Space Center, MS. I was able to calculate the minerogenic scattering coefficient for the Oceanside, California field exercise of July, 1997 based on information provided by Dr. Keen derived from first principles of physics and hydrodynamics. Detailed predictions based on more complete information from this and other field sites are currently underway.

RESULTS

Predictions for the mass and size distribution of resuspended quartz sand and silt were provided for the dates of 14. July 1997 (strong wave action) and 24. July 1997 (calm and relatively little wave action) by Dr. Timothy Keen. His 4-D Coastal Ocean Currents model provided the following estimates for the concentration and modal size class of resuspended minerogenic matter at a depth of 0.1 m: 111,685,842 particles m^{-3}, modal diameter 13 μm, 14. July 1997, and 87,666 particles m^{-3}, modal diameter 3 μm, 24. July 1997. The modal particle diameter and the relative concentrations for the two dates remained virtually unchanged for the depths sampled in the model predictions. For a wavelength of 532 nm and a real refractive index of 1.25 with no absorption in the particulates (reasonable assumptions for the particulates of Oceanside, CA on those dates) Mie calculations were performed on the size distributions of the particulates from near the bottom to 2.35 m from the bottom.

14. July 1997		24. July 1997	
Distance from Bottom (m)	b_p (m^{-1})	Distance from Bottom (m)	b_p (m^{-1})
0.04825	26.2893	5E-06	0.3043
0.1012	9.7373	0.04677	0.0002
0.4489	4.2071	0.09748	0.0002
1.027	2.7926	0.4235	0.0002
1.43	2.3060	1.127	0.0002
2.35	1.6335	1.44	0.0002
		2.35	0.0002

The total beam attenuation coefficient that has been recorded at Oceanside ranges from about 0.3 m^{-1} near the surface to 4.0 m^{-1} to within 1 or 2 meters off the bottom. We see that

the scattering due to resuspended quartz-like particulates can represent a significant percentage of the total beam attenuation coefficient on days with significant wave stress while on days of lessened wave stress the scattering of resuspended quartz-like particles probably represents a lesser percentage of the total beam attenuation coefficient. One important result of this effort is the ability to predict the concentration of resuspended particulates near the bottom, distances of 0.1 meter off the bottom and less, that are difficult to measure directly with optical devices such as the AC-9 meter and related devices. Even on the calm date of 24. July 1997 the minerogenic matter near the bottom boundary layer had a significant optical effect. Thus, we have the potential here to generate meaningful optical predictions and models for coastal, Type 2 optical water types from the predictions of coastal ocean current models.

IMPACT/APPLICATION

These simulations with accurate estimates of minerogenic matter will give the information necessary to fashion Type 2 coastal optical models, algorithms, and predictions of optical properties. A high or zenith sun in this effort to model the photon penetration in a coastal system will generate results that will allow improvement of active remote sensing algorithms in terms of the expected return from a laser probe. Underwater visibility studies will benefit from considerations of multiple scattering and multiple internal reflections accounted for by a Type 2 model based on the 3-Parameter Model in addition to factoring in minerogenic particles validly.

TRANSITIONS

Frank Hoge, NASA - Wallops Island, VA, is applying the results our Type 2 simulations with minerogenic matter and shape factor effects to the backscattering shape factor in his active remote sensing work in coastal regions. In the Remote Sensing Branch of the Naval Research Laboratory, Stennis Space Center, Sonia Gallegos wishes to apply these results to remote-sensing algorithms of the Yellow Sea as does Rick Gould for high minerogenic coastal remote sensing algorithms.

RELATED PROJECTS

Herewith I list the projects being pursued concurrently with the Littoral Optical Environment initiative of the Naval Research Laboratory and the Office of Naval Research.

1 - Timothy R. Keen, Ocean Sensing and Prediction Branch (Code 7322), Naval Research Laboratory, Stennis Space Center, MS is working closely with me to provide the latest results on prediction of mass, size distribution, and type of resuspended minerogenic material. This is being done through the Very High Resolution 4-D Coastal Ocean

Currents Program element 62435N of ONR.

2 - Douglas Neilsen, Coupled Dynamic Processes Section (Code 7331), Ocean Sciences Branch (Code 7330), Naval Research Laboratory, Stennis Space Center, MS has been working with me to determine optimal wavebands to utilize in a surface layer model of hydrodynamically forced primary productivity in the Arabian Sea. This is done with respect to the absorbing and scattering conditions of the major species of suspended cells.

3 - Dariusz Stramski, Marine Physical Laboratory, Scripps Institution of Oceanography, UCSD, La Jolla, CA has recently published a database of optical properties of living and organic suspended particles (Stramski and Mobley, 1997). He has supplied me with this database and we will be using it in various radiative transfer simulations. We will jointly publish the more interesting results of this endeavor.

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